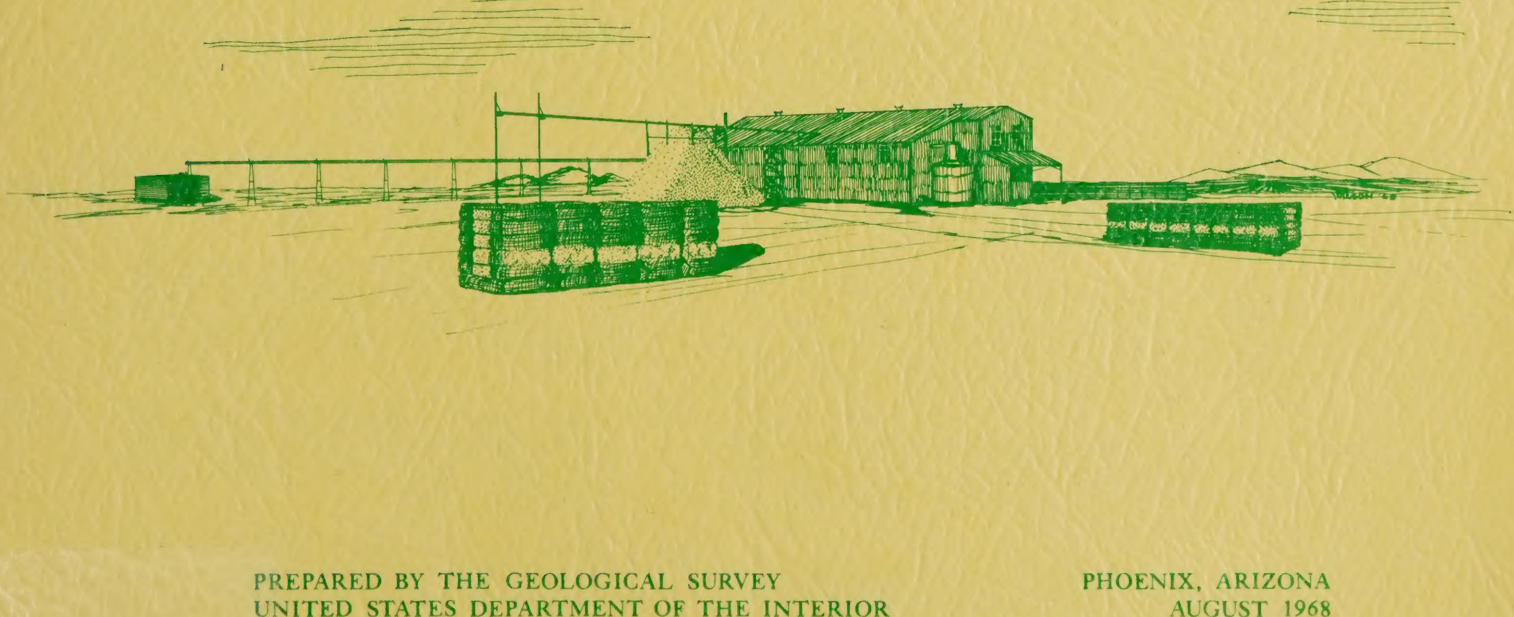
WATER-RESOURCES REPORT NUMBER THIRTY-SEVEN
ARIZONA STATE LAND DEPARTMENT
OBED M. LASSEN, COMMISSIONER

GROUND-WATER CONDITIONS IN THE WATERMAN WASH AREA, MARICOPA AND PINAL COUNTIES, ARIZONA

BY E. E. DENIS



PREPARED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

PHOENIX, ARIZONA
AUGUST 1968

ARIZONA STATE LAND DEPARTMENT WATER-RESOURCES REPORTS

The following reports are available for distribution at the Arizona State Land Department, 422 State Office Building, Phoenix, and at U. S. Geological Survey offices in: 2555 East First Street, Tucson; and 5017 Federal Building, 230 North First Avenue, Phoenix. Those marked with an asterisk (*) are out of print and are available on loan only from the U. S. Geological Survey, 2555 East First Street, Tucson.

No.

* 1. Pumpage and ground-water levels in Arizona in 1955, by P. W. Johnson, N. D. White, and J. M. Cahill: 69 p., 30 figs., 1956.

* 2. Annual report on ground water in Arizona, spring 1956 to spring 1957, by J. W. Harshbarger and others: 42 p., 18 figs., 1957.

* 3. Geology and ground-water resources of the Harquahala Plains area, Maricopa and Yuma Counties, Arizona, by D. G. Metzger: 40 p., 2 pls., 7 figs., 1957.

* 4. Geology and ground-water resources of the Palomas Plain-Dendora Valley area, Maricopa and Yuma Counties, Arizona, by C. A. Armstrong and C. B. Yost, Jr.: 49 p., 3 pls., 4 figs., 1958.

* 5. Annual report on ground water in Arizona, spring 1957 to spring 1958, by W. F. Hardt, J. M. Cahill, and M. B. Booher: 60 p., 19 figs., 1958.

* 6. Annual report on ground water in Arizona, spring 1958 to spring 1959, by W. F. Hardt, R. S. Stulik, and M. B. Booher: 61 p., 18 figs., 1959.

* 7. Annual report on ground water in Arizona, spring 1959 to spring 1960, by W. F. Hardt, R. S. Stulik, and M. B. Booher: 89 p., 22 figs., 1960.

* 8. Geology and ground-water resources of the McMullen Valley, Maricopa, Yavapai, and Yuma Counties, Arizona, by William Kam: 72 p., 17 figs., 1961.

9. Hydrologic data and drillers' logs, Papago Indian Reservation, Arizona, by L. A. Heindl and O. J. Cosner, with a section on chemical quality of the water by L. R. Kister: 116 p., 3 figs., 1961.

*10. Annual report on ground water in Arizona, spring 1960 to spring 1961, by N. D. White, R. S. Stulik, E. K. Morse, and others: 93 p., 32 figs., 1961.

*11. Annual report on ground water in Arizona, spring 1961 to spring 1962, by N. D. White, R. S. Stulik, and others: 116 p., 35 figs., 1962.

No.

*12A. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part I, Records of ground-water supplies, by G. E. Davis, W. F. Hardt, L. K. Thompson, and M. E. Cooley: 159 p., 3 figs., 1963.

*12B. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part II, Selected chemical analyses of the ground water, by L. R. Kister and J. L. Hatchett: 58 p., 2 figs., 1963.

12C. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part III, Selected lithologic logs, drillers' logs, and stratigraphic sections, by M. E. Cooley, J. P. Akers, and P. R. Stevens: 157 p., 3 figs., 1964.

12D. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part IV, Maps showing locations of wells, springs, and stratigraphic sections, by M. E. Cooley and others: 2 sheets, 1966.

12E. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part I-A, Supplemental records of ground-water supplies, by E. H. McGavock, R. J. Edmonds, E. L. Gillespie, and P. C. Halpenny: 55 p., 4 figs., 1966.

13. Desert floods—a report on southern Arizona floods of September 1962, by D. D. Lewis: 13 p., 18 figs., 1963.

*14. Basic ground-water data of the Willcox basin, Graham and Cochise Counties, Arizona, by S. G. Brown, H. H. Schumann, L. R. Kister, and P. W. Johnson: 93 p., 15 figs., 1963.

*15. Annual report on ground water in Arizona, spring 1962 to spring 1963, by N. D. White, R. S. Stulik, E. K. Morse, and others: 136 p., 47 figs., 1963.

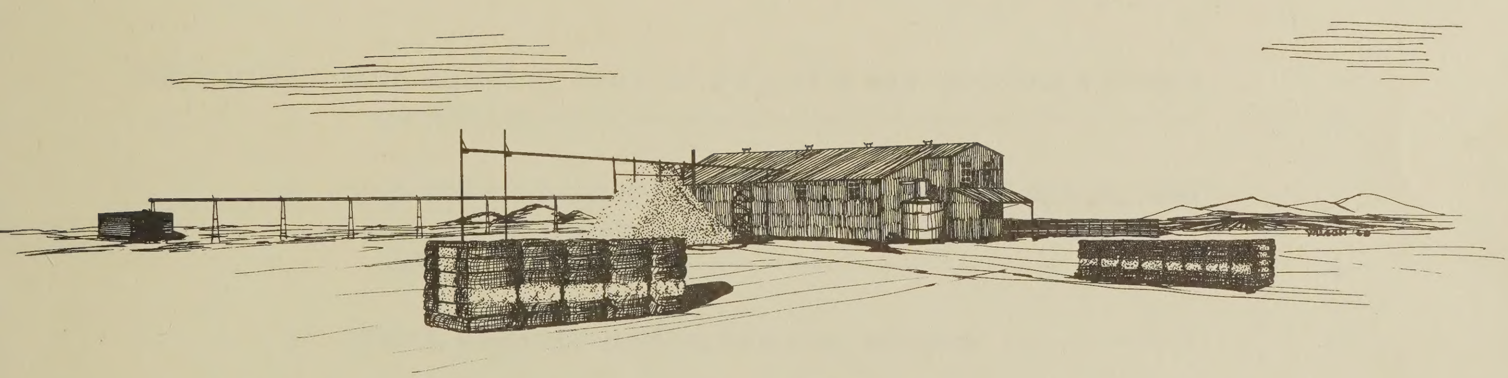
16. Effects of ground-water withdrawal in part of central Arizona projected to 1969, by N. D. White, R. S. Stulik, and C. L. Rauh: 25 p., 7 figs., 1964.

(Continued on inside back cover)

WATER-RESOURCES REPORT NUMBER THIRTY-SEVEN
ARIZONA STATE LAND DEPARTMENT
OBED M. LASSEN, COMMISSIONER

GROUND-WATER CONDITIONS IN THE WATERMAN WASH AREA, MARICOPA AND PINAL COUNTIES, ARIZONA

BY E. E. DENIS



PREPARED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

PHOENIX, ARIZONA
AUGUST 1968

CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER CONDITIONS IN THE WATERMAN WASH AREA, MARICOPA AND PINAL COUNTIES, ARIZONA

By

E. E. Denis

Introduction

The ground-water reservoir is the only dependable source of water in the Waterman Wash area (fig. 1), and it is important that this supply be managed properly for the equal benefit of all concerned with the economic growth of the area. Therefore, a comprehensive knowledge of all the factors that affect the ground-water reservoir is necessary.

As a part of the continuing ground-water program in Arizona, the U. S. Geological Survey, in cooperation with the Arizona State Land Department, O. M. Lassen, Commissioner, collects data on the occurrence and development of ground water in the State. For the most part, the data presented in this report were collected as a part of the continuing program, although some additional fieldwork was done from August 1965 through January 1966. The study was conducted under the immediate supervision of H. M. Babcock, district chief of the Water Resources Division of the U. S. Geological Survey in Arizona. This report describes the ground-water conditions and water-level trends in the Waterman Wash area and makes available the basic data that have been acquired since publication of the comprehensive report (White, 1963).

Many people in the area provided useful information for this study. The author especially wishes to acknowledge the cooperation of the personnel of the Arizona Public Service Co., who provided data for the computation of the amount of ground water pumped in the area.

The reports describing previous hydrologic investigations in the Waterman Wash area are listed below.

1952. Wolcott, H. N., Rainbow Valley-Waterman Wash area, Maricopa County, <u>in</u> Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 151-158.

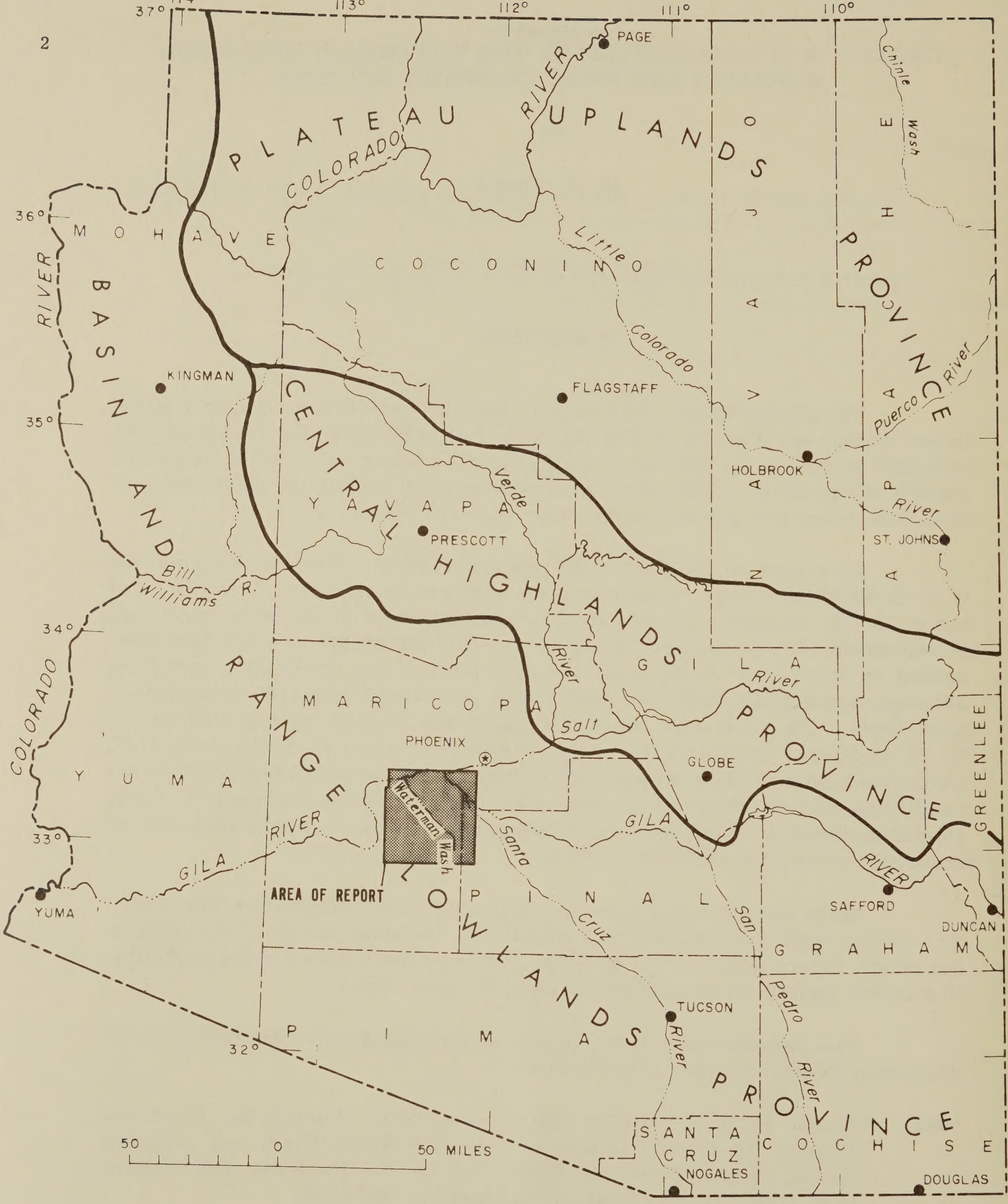


FIGURE 1.--AREA OF REPORT AND ARIZONA'S WATER PROVINCES.

1953. Wolcott, H. N., Memorandum on ground-water resources and geology of Rainbow Valley-Waterman Wash area, Maricopa County, Arizona: U. S. Geol. Survey open-file report, 13 p.

1963. White, N. D., Ground-water conditions in the Rainbow Valley and Waterman Wash areas, Maricopa and Pinal Counties, Arizona: U. S. Geol. Survey Water-Supply Paper 1669-F, 50 p.

The Waterman Wash area, which is southeast of Buckeye in south-central Arizona, is a northwest-trending valley bounded by the Buckeye Hills on the north, the Haley and Booth Hills and the Palo Verde Mountains on the south, the Sierra Estrella on the east, and the Maricopa Mountains on the west (fig. 2). Waterman Wash is a northwestward-flowing ephemeral stream that is tributary to the Gila River; it drains about 400 square miles and flows out of the area through a narrow gap in the Buckeye Hills. The valley floor is about 25 miles long and averages about 8 miles wide.

The climate of the Waterman Wash area is arid and is characterized by hot summers and mild winters; hence, year-round crop production is possible. The mean annual temperature is about 70°F, and mean monthly temperatures range from about 51°F in January to 91°F in July. The mean annual precipitation is about 7½ inches. In 1965 average temperatures and precipitation did not differ significantly from the long-term averages (U. S. Weather Bureau, issued annually).

Agricultural development in the Waterman Wash area is comparatively recent. In 1952 only 3,500 acres of land was cultivated (Wolcott, 1953); by 1961 the amount of land under cultivation had increased to about 16,000 acres (White, 1963). A field inventory in the summer of 1965 showed that about 19,000 acres of land was cleared for cultivation but that only 10,000 acres was being irrigated (fig. 2). Irrigation water for the area under cultivation was being pumped from 44 wells. Information regarding the wells is given in table 1 (see appendix), and the locations of the wells are shown in figure 2. All well locations in the area are described according to the well-numbering system used in Arizona (fig. 3).

The U.S. Geological Survey has recently (1967) changed the method of reporting Survey water-quality data from the English system to the metric system. Therefore, the water-quality data in this report are given in milligrams per liter (mg/l), degrees Celsius (°C), and micromhos at 25°C. The terms "parts per million" and "milligrams per liter" are practically synonymous for water containing as much as 5,000 to 10,000 mg/l of dissolved solids. The exact amount is dependent on the nature of the dissolved material. The Survey has set 7,000 mg/l dissolved solids as the point above which the difference in parts per million and milligrams per liter becomes

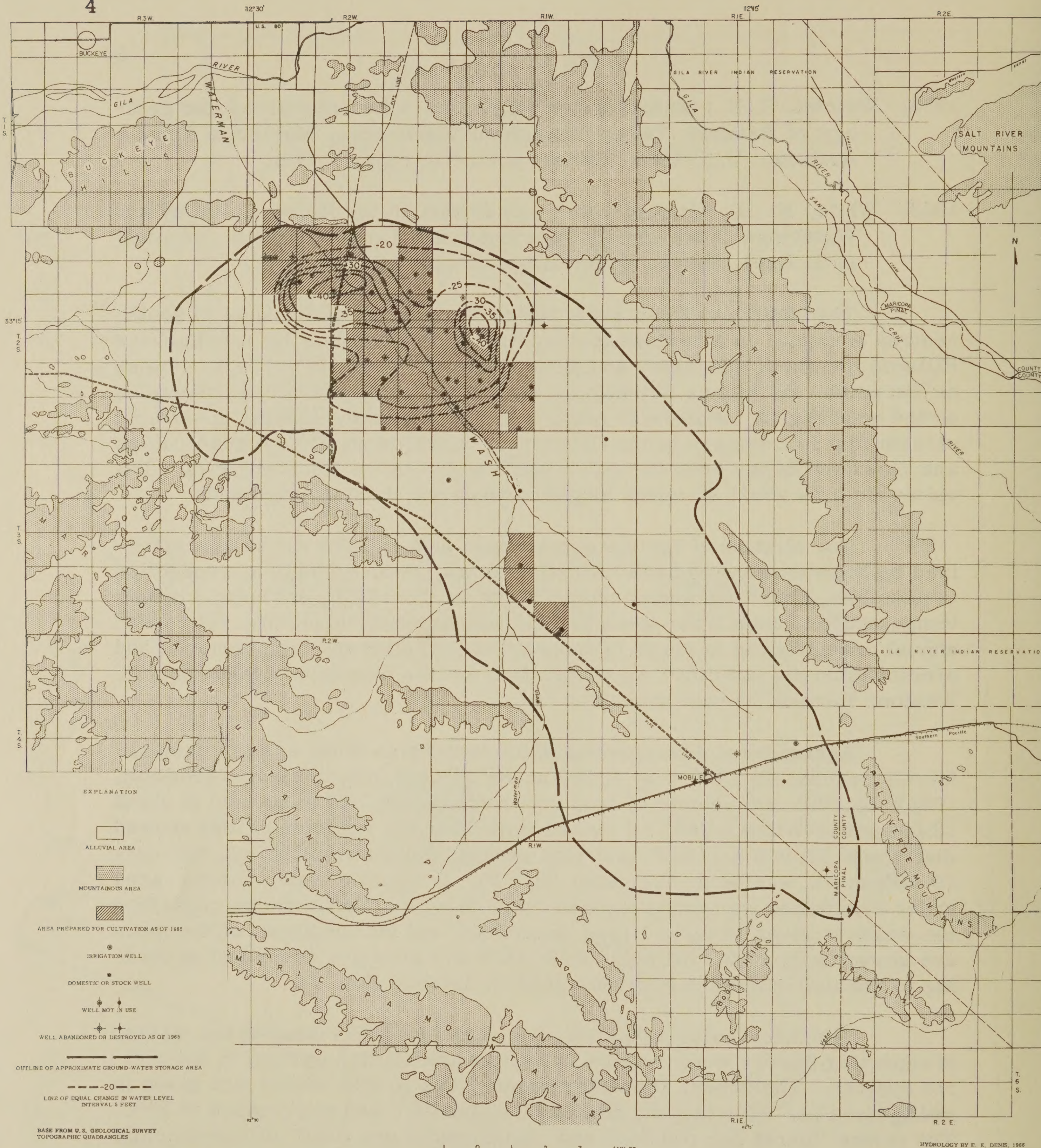
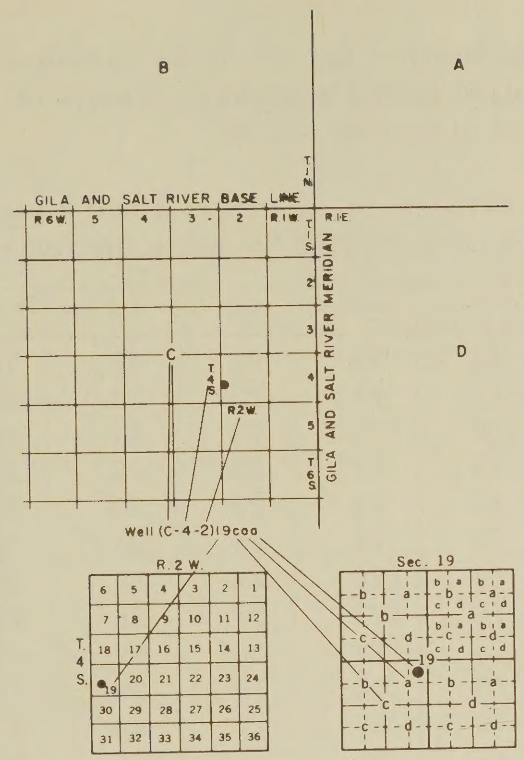


FIGURE 2.--LOCATION OF WELLS, CULTIVATED AREAS, AND CHANGE IN WATER LEVELS FROM SPRING 1961 TO SPRING 1966 IN THE WATERMAN WASH AREA.



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (C-4-2)19caa designates the well as being in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 2 W. Where there is more than one well within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 3. --Well-numbering system in Arizona.

significant. In order to convert data from one system to the other, a density factor must be applied to the analytical results of all water containing more than 7,000 mg/l of dissolved solids.

Temperature data given in tables 2 and 3 (see appendix) can be converted to degrees Fahrenheit (°F) by using the following:

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
32	0	51	11	70	21	89	32	108	42
33	1	52	11	71	22	90	32	109	43
34	1	53	12	72	22	91	33	110	43
35	2	54	12	73	23	92	33	111	44
36	2	55	13	74	23	93	34	112	44
37	3	56	13	75	24	94	34	113	45
38	3	57	14	76	24	95	35	114	46
39	4	58	14	77	25	96	36	115	46
40	4	59	15	78	26	97	36	116	47
41	5	60	16	79	26	98	37	117	47
42	6	61	16	80	27	99	37	118	48
43	6	62	17	81	27	100	38	119	48
44	7	63	17	82	28	101	38	120	49
45	7	64	18	83	28	102	39	121	49
46	8	65	18	84	29	103	39	122	50
47	8	66	19	85	29	104	40		
48	9	67	19	86	30	105	41		
49	9	68	20	87	31	106	41		
50	10	69	21	88	31	107	42		

Ground Water

The occurrence of ground water in the Waterman Wash area is similar to that in many areas of the Basin and Range lowlands of Arizona. Ground water is in the sand and gravel of the alluvial fill, which is present to depths of more than 1,500 feet in parts of the area. Most of the ground water in the area is under water-table conditions, although some water may be under artesian pressure in places. The depth to water is greatest at the south end of the area and along the east edge adjacent to the Sierra Estrella (fig. 4). In spring 1966 the depth to water in two wells near Mobile was about 400 feet below the land surface; at the south edge of the developed area, the depth to water was more than 350 feet below the land surface. At the northwest end of the area, the depth to water was about 225 feet in spring 1966.

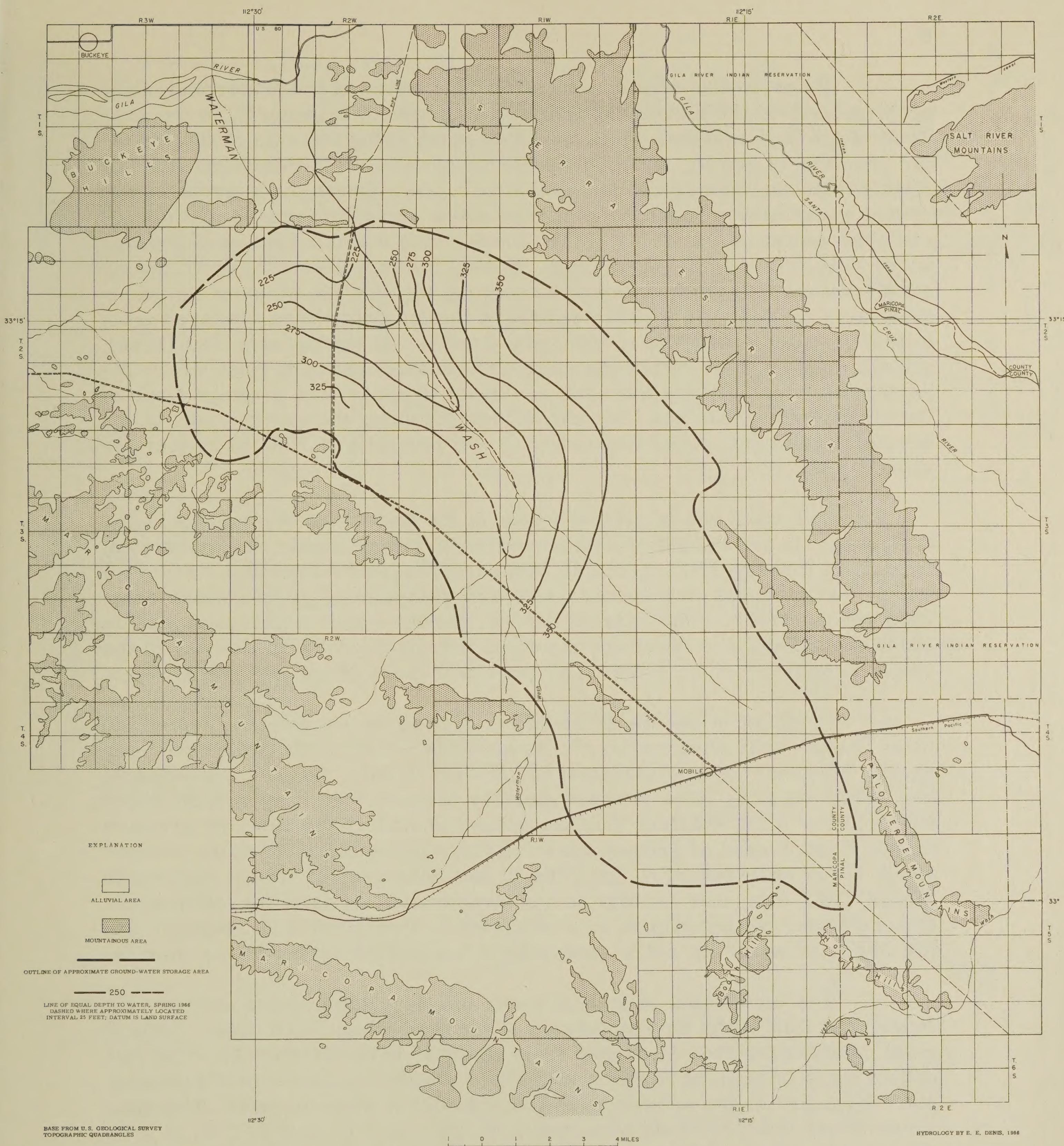


FIGURE 4.--DEPTH TO WATER, SPRING 1966, IN THE WATERMAN WASH AREA.

Prior to the development of ground water in the Waterman Wash area, ground-water movement probably conformed, in general, to the gradient of the land surface. From south to north along the axis of the valley, the gradient is gentle, and ground-water movement in this direction was slight; from the mountains toward the axis, the slope is much greater, and ground water moved from the recharge areas along the mountain fronts toward the center of the valley. In 1952, when only a small amount of ground-water development had taken place, ground water was moving from nearly all directions toward the center of pumping; by 1961 the slope of the water table from the bedrock boundaries toward the developed area averaged about 15 to 20 feet per mile (White, 1963, pls. 2 and 3). At the present time (1966), ground water moves toward the center of greatest pumping from every direction but most notably from the southeast (fig. 5). The average slope of the ground-water surface from south to north along the central part of the developed area increased from about 7 feet per mile in 1961 to 11 feet per mile in 1966.

The main use of ground water in the Waterman Wash area is for irrigation. In 1965 about 45,000 acre-feet of ground water was withdrawn; from 1961 through 1965 about 260,000 acre-feet was withdrawn. Figure 6 shows water levels in selected wells and pumpage of ground water from 1952 through 1965. The largest annual ground-water withdrawal was in 1961; the subsequent decrease in annual pumpage probably was due to the use of tailwater-return systems to provide a part of the irrigation water.

Pumping in the Waterman Wash area is on a continuing basis, and many wells—not necessarily the same wells—are in operation the year round. Ground-water withdrawal is greatest in July, August, and September, when the long-term average monthly temperature ranges from about 84°F to 91°F (U. S. Weather Bureau, issued annually). In 1965 the greatest monthly withdrawal of ground water was in August, when 40 wells pumped about 7,150 acre-feet (fig. 7). The 5,300 acre-feet of water pumped in March 1965 was used mainly in the preparation of land for cultivation. Ground-water withdrawal is at a minimum in December and January, and the depth to water in wells generally is measured during these months.

The withdrawal of ground water has resulted in a general decline in water levels in the developed part of the Waterman Wash area. Water-level declines for 1961-66 ranged from about 20 to 40 feet (fig. 2). The rate of decline is influenced by the distribution of pumping, the rate of pumping, and the texture of the sediments in the area of the pumping well. The maximum water-level declines occurred in T. 2 S., R. 1 W. and T. 2 S., R. 2 W. As noted by White (1963, p. 48), the cone of depression created by pumping covered about 45,000 acres in 1961; by 1966, the cone had expanded and covered more than 60,000 acres.

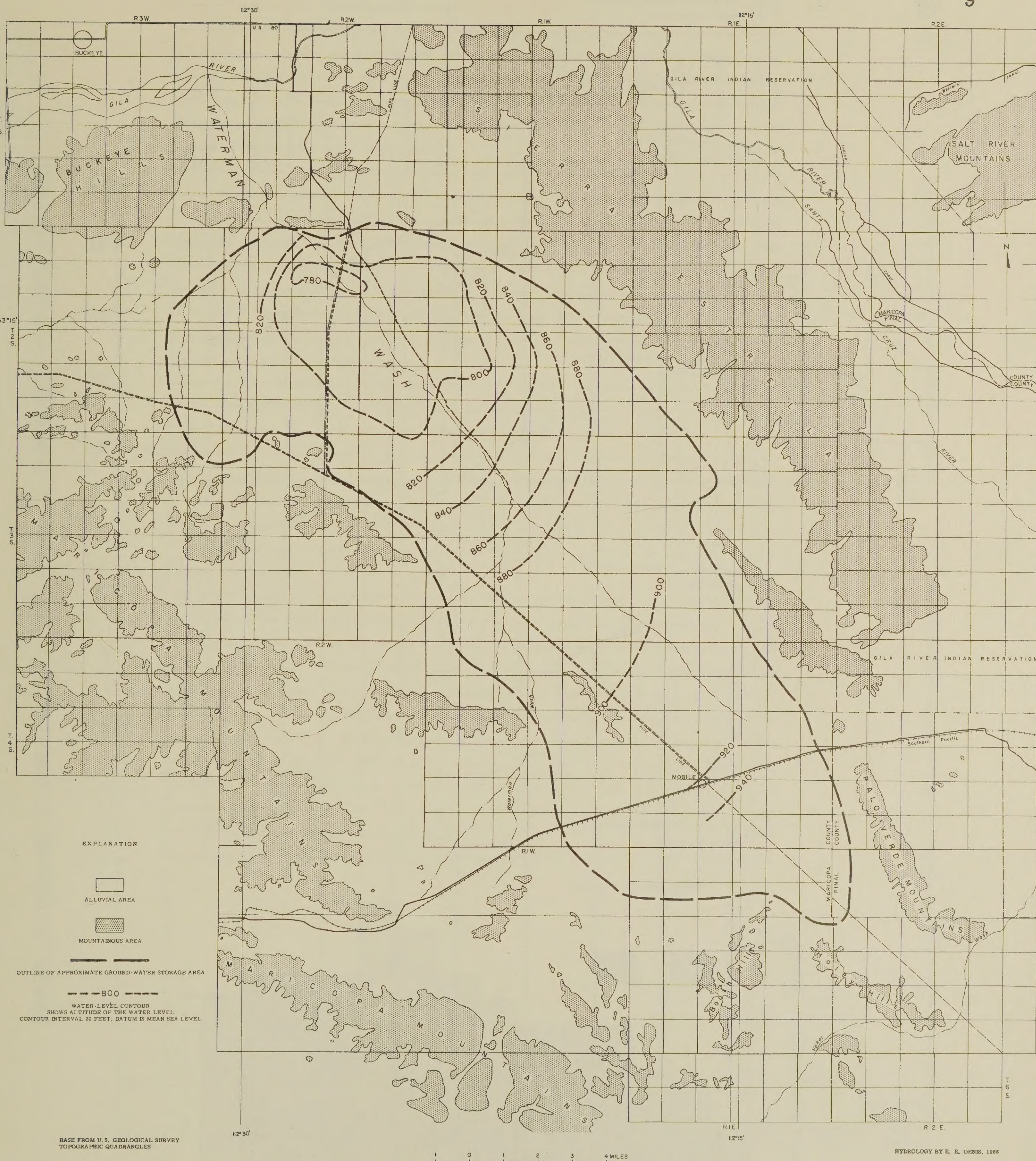


FIGURE 5.--WATER-LEVEL CONTOURS, SPRING 1966, IN THE WATERMAN WASH AREA.

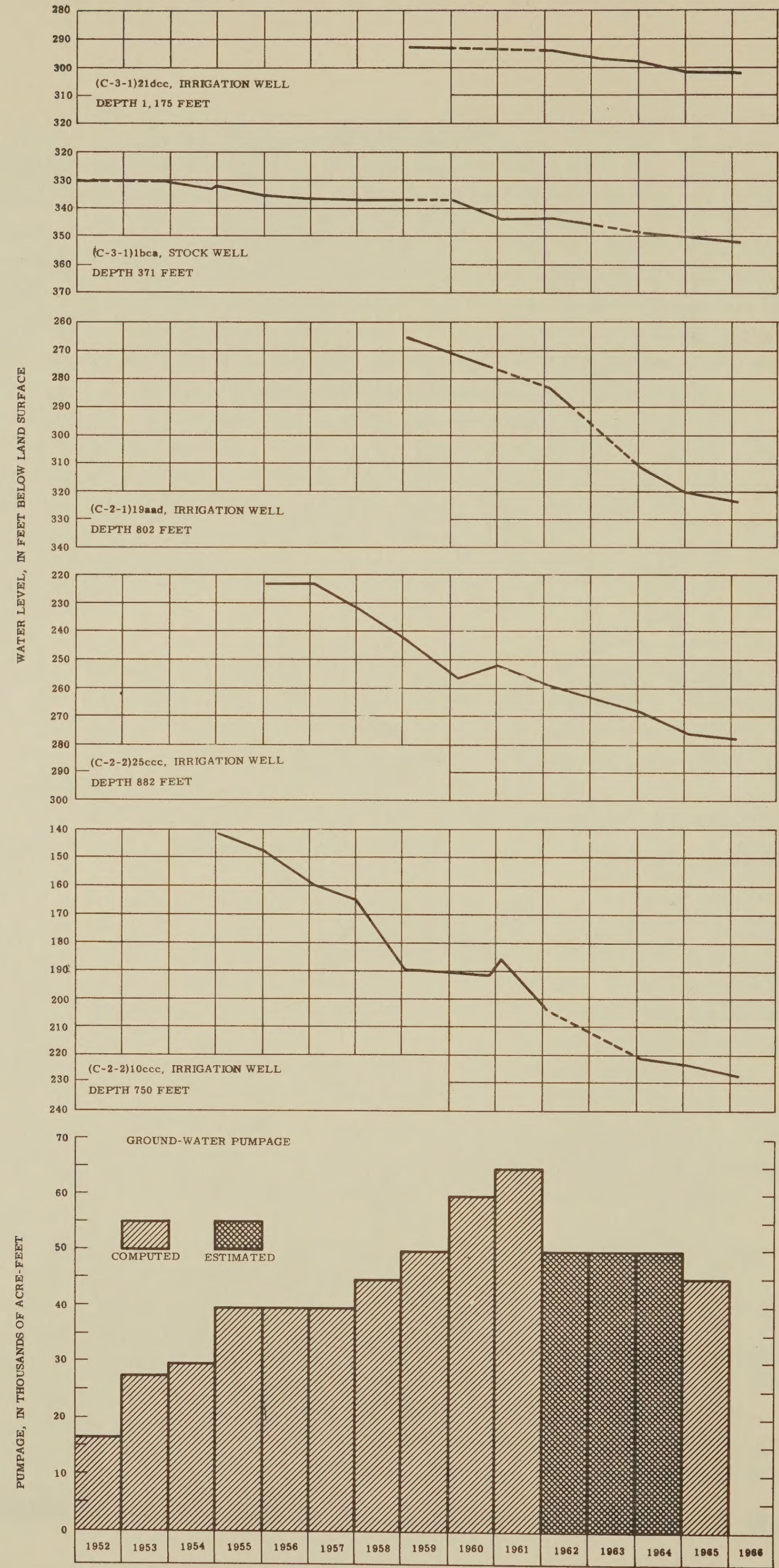


FIGURE 6.--WATER LEVELS IN SELECTED WELLS AND ANNUAL PUMPAGE.

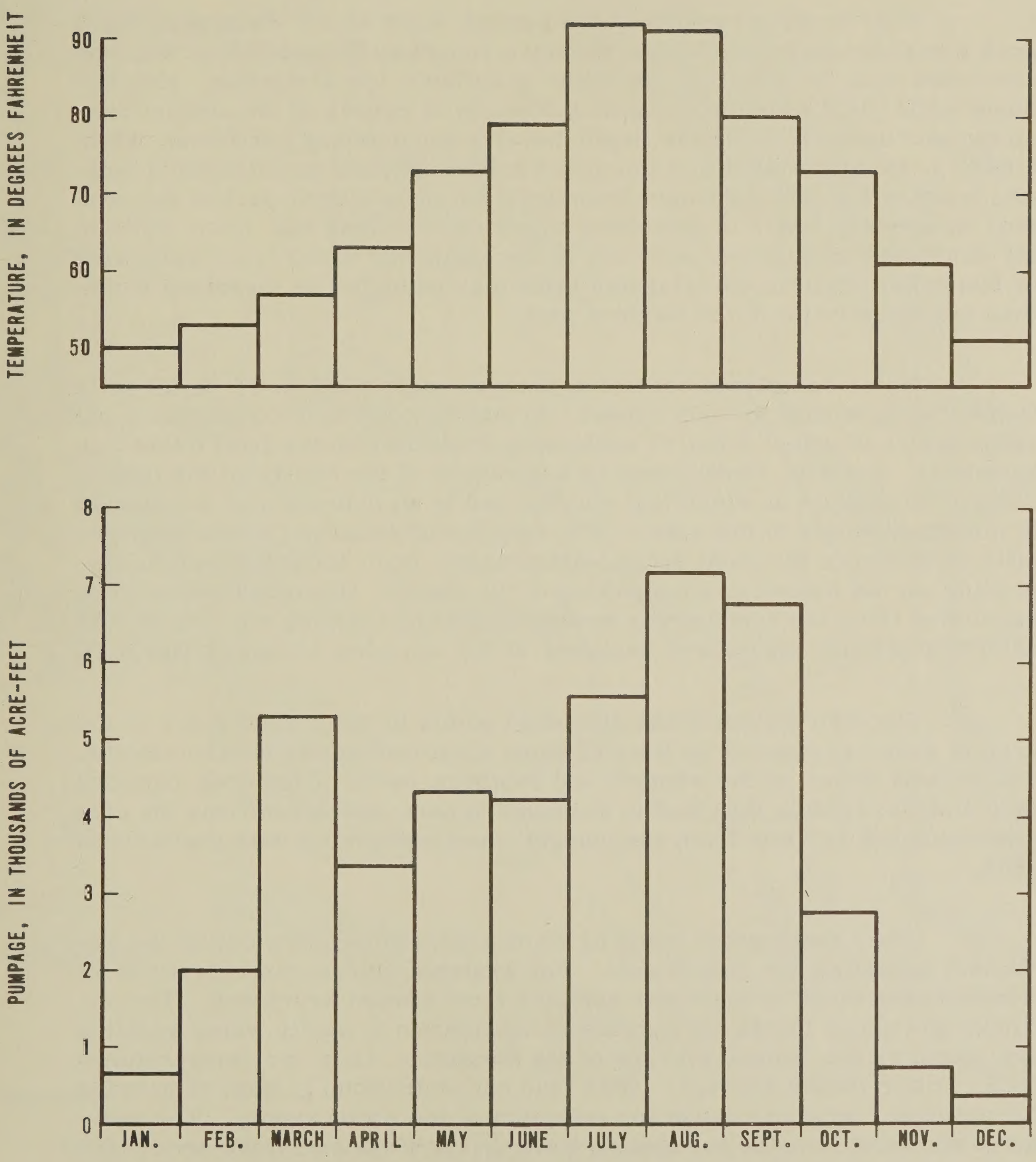


FIGURE 7.--MONTHLY AVERAGE AIR TEMPERATURE AND MONTHLY PUMPAGE, 1965.

Chemical Quality of the Ground Water

The chemical quality of the ground water in the Waterman Wash area was discussed in the comprehensive report by White (1963, p. 48), who concluded that, in general, the water is suitable for irrigation, although some wells yield water that contains fluoride in excess of the amount recommended by the U. S. Public Health Service for drinking purposes. White (1963, p. 48) also stated that the data were insufficient to establish a definite pattern but that the water from wells in the southern part of the area may be slightly lower in dissolved-solids content than that from wells in the developed area at the north end of the basin; the water from wells east of Waterman Wash in the irrigated area may be higher in dissolved solids than that from wells in the western part.

Water samples for chemical analysis were collected from 29 wells (table 2 in appendix) for this report. In addition, specific conductance and temperature of water from 11 wells were measured in the field (table 3 in appendix). Specific conductance is a measure of the ability of the ions in solution to conduct an electrical current and is an indication of the amount of dissolved solids in the water. The relation of dissolved solids and specific conductance for most fresh water ranges from about 0. 5 to 0. 7, depending on the chemical composition of the water. Dissolved solids were calculated from the conductivity measurements by applying a factor of 0.56 determined from laboratory analyses of the samples collected (table 3).

The distribution of the dissolved solids in the ground water in the area is shown in figure 8 by lines of equal dissolved-solids concentrations. The ground water in the western and southern parts of the area contains less dissolved solids than that in the eastern part, which confirms the conclusions made by White from the meager chemical-quality data available in 1963.

Other conclusions made by White (1963) were borne out by the additional sampling for this report. For example, large concentrations of fluoride were found in the water samples from almost every well. The optimum and upper limits for fluoride concentration in public water supplies are based on the annual average of the maximum daily air temperatures (U. S. Public Health Service, 1962), and concentrations greater than twice the optimum value are cause for rejection of the water supply. The optimum amount of fluoride in drinking water in the Waterman Wash area is 0.7 mg/l. All the water sampled contained more than this amount, and about 90 percent contained more than 1. 4 mg/l, which is cause for rejection.

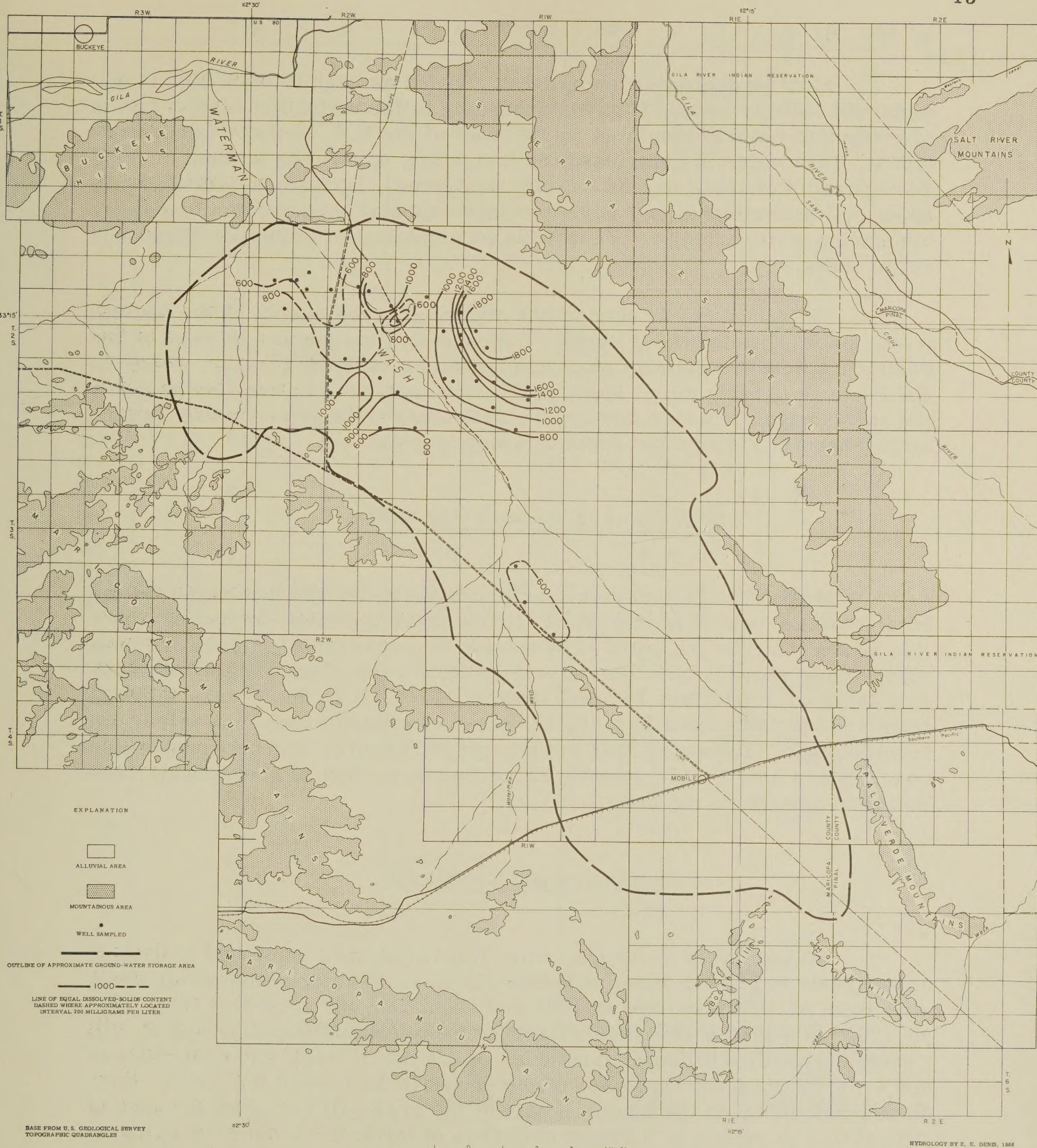


FIGURE 8.--DISSOLVED-SOLIDS CONTENT OF THE GROUND WATER IN THE WATERMAN WASH AREA.

Most of the water sampled is classed as high to very high in sodium and salinity hazard (fig. 9), according to the method of classification of irrigation water formulated by the staff of the U. S. Salinity Laboratory (1954). This water is being used for irrigation, apparently without causing widespread soil alkalinity or salinity problems. Irrigators, however, do apply soil amendments and have developed special management practices of draining and leaching to prevent the accumulation of harmful alkaline and saline salts.

No recognizable change has occurred in the quality of the ground water since White's (1963) study. Undoubtedly, the amount of salts in the sediments between the root zone and the water table is greater, owing to the increase in irrigation. Many years, however, may be required to move the salty irrigation water through the sediments to the ground-water reservoir, especially where the depth to water is great.

Volume of Recoverable Water

Most of the ground water pumped in the Waterman Wash area comes from storage, and it is important to determine the total amount of water that is available for pumping. The volume of recoverable ground water was computed at about 9. 5 million acre-feet in an area of about 120, 000 acres to a depth of 1, 000 feet (White, 1963, p. 40-41). In the 5-year interval from 1961 to 1965 about 260, 000 acre-feet of ground water was withdrawn from storage. Assuming that the amount of recharge to the ground-water reservoir is small, then about 9. 25 million acre-feet of ground water remains in storage in the area.

Summary and Conclusions

Water levels in the Waterman Wash area have continued to decline in response to ground-water withdrawal. Ground-water withdrawal, which was about 45, 000 acre-feet in 1965 and about 260, 000 acre-feet from 1961 to 1965, is causing the cone of depression to expand rapidly, and it will eventually abut the bedrock boundaries on the north, east, and west sides of the area. Subsequent expansion of the cone will be toward the south. Further development in the southern part of the area will cause local cones of depression to expand in a broadening area of influence around the pumping wells; when the local cones and the southward-moving cone coalesce, a more rapid depletion of ground-water storage will occur. The available ground water remaining in storage in 1965 is estimated to be about 9,240,000

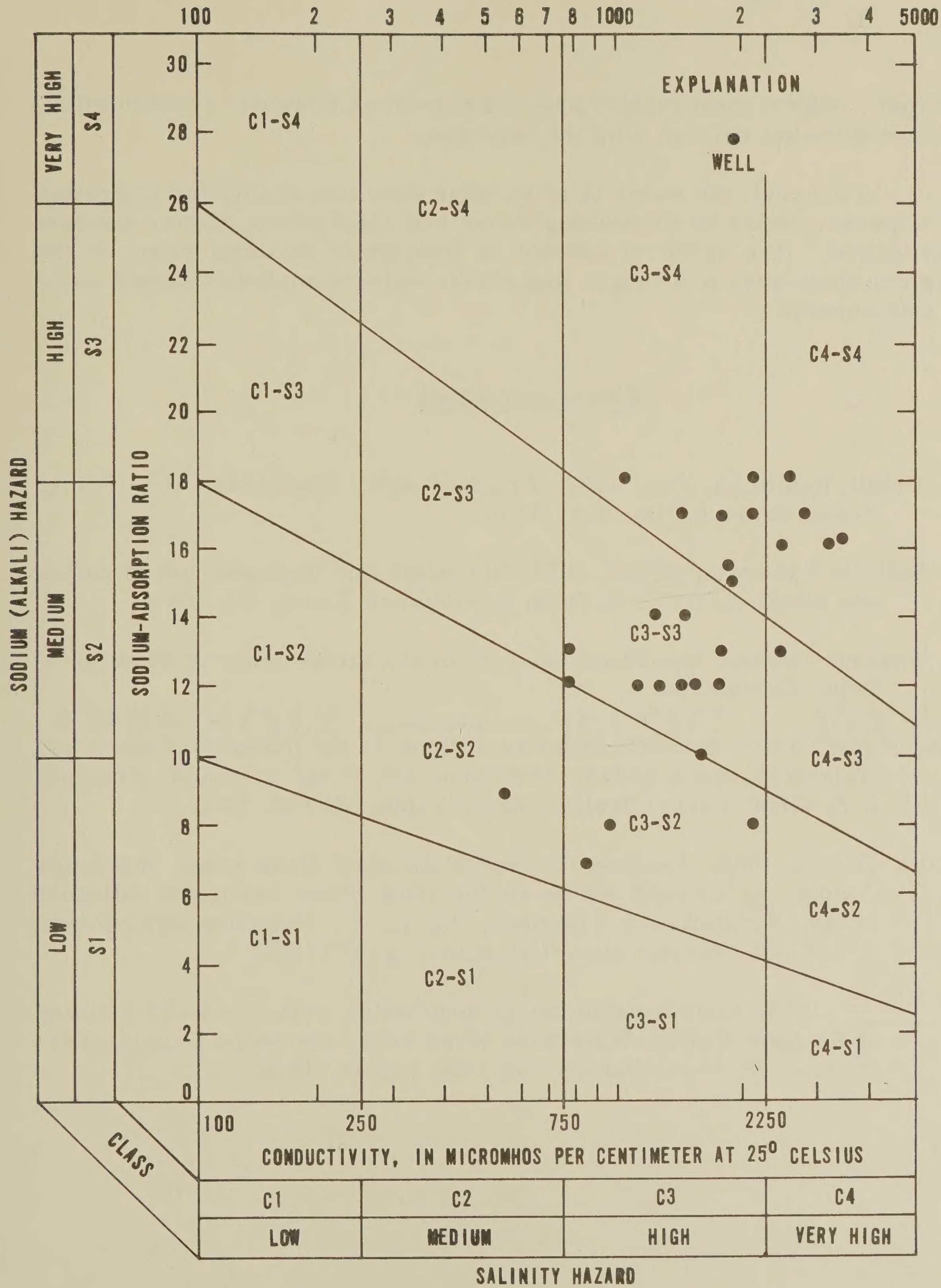


FIGURE 9.--SODIUM AND SALINITY HAZARD OF GROUND WATER. DIAGRAM ADOPTED FROM U.S. SALINITY LABORATORY STAFF (1954).

acre-feet. Water conservation practices, such as tailwater recirculation, will slow down but will not stop the depletion.

In general, the water is of suitable chemical quality for irrigation use; however, owing to increasing reuse and infiltration, it may become highly saline. The optimum amount of fluoride in drinking water in the Waterman Wash area is 0.7 mg/l, and all the water sampled contained more than this amount.

References Cited

U. S. Public Health Service, 1962, Drinking water standards: U. S. Public Health Service Pub. 956, 61 p.

U. S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. Agriculture Handb. 60, 160 p.

U. S. Weather Bureau, issued annually, Climatological data, Arizona: U. S. Dept. Commerce.

White, N. D., 1963, Ground-water conditions in the Rainbow Valley and Waterman Wash areas, Maricopa and Pinal Counties, Arizona: U. S. Geol. Survey Water-Supply Paper 1669-F, 50 p.

Wolcott, H. N., 1952, Rainbow Valley–Waterman Wash area, Maricopa County, in Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 151-158.

__________ 1953, Memorandum on ground-water resources and geology of Rainbow Valley–Waterman Wash area, Maricopa County, Arizona: U. S. Geol. Survey open-file report, 13 p.

APPENDIX —— BASIC DATA

Table 1.--Records of wells in the Waterman Wash area

Location: See p. for description of well-numbering system.
Land-surface altitude: Determined from Geological Survey topographic maps.
Perforated interval: OH, open hole.
Water level: R, reported; measured water levels are given to nearest tenth of a foot.

Yield: R, reported; E, estimated; measured yields are given to the nearest 10 gpm (gallons per minute).
Well log: X, log available.
Chemical analysis: X, chemical analysis included in table 2.

Well location	Land-surface altitude (feet above mean sea level)	Date completed (year)	Reported depth (feet)	Diameter of casing (inches)	Depth of casing (feet)	Perforated interval (feet below land surface)	Water level		Pumping data			Well log	Chemical analysis	Remarks
							Date (month, year)	Feet below land surface	Date (month, year)	Yield (gpm)	Pumping level (feet below land surface)			
(C-2-1)15cdc	1,236	----	---	6	---	----	2/51 11/53	312.6 313.5	---	---	----	---	---	
16add	1,210	----	---	6	---	----	6/52 12/65	315.8 367.8	---	---	----	---	---	
18aaa	1,120	1953	953	20-16	---	----	9/60 12/65	312.5 329.2	---	---	----	X	---	
18daa	1,117	1953	958	20-16	---	----	12/53 12/65	240.0 331.4	8/65	1,210	460.0	---	X	
19aad	1,106	1955	802	20-16	802	297-621 639-802	1/59 12/65	265.7 323.0	---	1,100	399.7	X	---	Hydrograph shown on figure 6.
19baa	1,095	1952	1,139	20-16	1,125	295-1,125 OH 1,125-1,139	2/54 12/65	223.4 308.1	8/65	1,610	427.0	X	---	
19daa	1,100	1962	---	---	---	----	12/65	321.8	8/65	1,220	389.8	---	X	
20baa	1,130	1964	1,549	16-12	1,549	248-1,549	12/65	340.8	8/65	1,440	383.0	X	X	
20bad	1,130	----	800	20	---	----	9/60 12/65	306.7 335.4	---	---	----	---	---	Formerly reported as (C-2-1)20baa (White, 1963).
20dba	1,135	1954	717	20-16	650	200-650 OH 650-717	8/54 12/65	260 R 337.7	8/65	2,280	392.5	X	X	
28bab	1,156	1959	870	16	870	176-870	9/60 1/66	326.8 346.8	8/65	1,500 E	----	X	---	
28dad	1,175	1959	805	20-16	805	176-805	12/65	338.6	8/65	1,490	425.9	X	X	
29bab	1,120	1952	809	20-16	809	120-809	10/52 1/66	218 R 330.3	8/65	1,460	378.3	X	X	
29caa	1,115	1952	809	20-16	809	200-809	2/54 1/66	234.6 306.9	8/65	1,140	372.5	X	---	
29daa	1,138	1959	936	20-16	936	256-936	1/61 1/66	295.2 319.9	8/65	1,810	390.5	X	X	
30bdd	1,080	1964	---	---	---	----	1/66	275.7	8/65	1,290	388.4	---	X	
30cdd	1,080	----	---	6	---	----	---	---	---	---	----	---	---	
30dba	1,090	1955	600	20	590	300-590 OH 590-600	/55 1/66	202 R 283.8	8/65	1,030	398.9	X	X	
31aca	1,085	1964	1,600	20-16	1,600	250-1,600	1/66	273.8	---	---	----	X	---	
32ada	1,128	1959	880	20-16	880	400-880	1/61 1/66	284.3 302.8	8/65	2,260	419.0	X	X	
33aaa	1,169	1950	1,030	20-16	1,000	240-1,000 OH 1,000-1,030	6/52 1/66	266.3 328.1	8/65	1,550	397.9	---	---	

Table 1.--Records of wells in the Waterman Wash area—Continued

Well location	Land-surface altitude (feet above mean sea level)	Date completed (year)	Reported depth (feet)	Diameter of casing (inches)	Depth of casing (feet)	Perforated interval (feet below land surface)	Water level		Pumping data			Well log	Chemical analysis	Remarks
							Date (month, year)	Feet below land surface	Date (month, year)	Yield (gpm)	Pumping level (feet below land surface)			
(C-2-1)33dcc	1,142	1961	1,073	20-16	1,073	200-1,073	2/61 1/66	296.8 300.0	---	---	----	X	X	
(C-2-2)1ccc	1,049	1950	585	Uncased	---	----	4/52 1/58	186.0 192.8	---	---	----	---	---	Destroyed.
3dcd	992	----	136	---	---	----	6/49 2/51	107.9 107.9	---	---	----	---	---	
5ccc	991	1953	725	20	---	----	2/54 1/59	102.1 132.4	---	---	----	X	---	Do.
5ccd	990	1954	594	16-14	592	290-398 402-592 OH 592-594	1/61 1/66	142.6 157.7	---	---	----	X	---	
5cdd	990	1954	1,089	16-14-12	1,037	421-1,037 OH 1,037-1,089	1/61 1/66	146.1 158.5	---	---	----	X	---	
5ddc	985	1950	1,122	---	---	----	2/51 2/57	95.2 118.7	---	---	----	X	---	Do.
8cad	1,015	1959	605	16	605	300-605	---	---	8/65	1,540	352.0	X	X	
8dad	1,015	1956	465	20	460	150-460 OH 460-465	1/61 1/66	198.2 235.3	8/65	1,930	350.1	X	---	
9bdd	1,000	1958	815	20-16	815	160-815	1/66	228.6	8/65	1,500	394.7	X	X	
9cbb	1,007	1954	973	20-16	973	180-973	1/55 1/66	134.9 232.4	8/65	2,050	427.2	---	X	
9cdd	1,020	1951	515	20	485	200-485 OH 485-515	4/52 1/61	132.5 222.8	8/65	1,560	375.4	X	---	
10ccc	1,015	1954	750	---	---	----	1/55 1/66	142.3 227.2	8/65	2,320	350.3	X	---	Hydrograph shown on figure 6.
10dda	1,010	1953	1,000	20	985	312-985 OH 985-1,000	11/53 12/65	134.5 232.0	8/65	2,820	310.8	X	X	
11ccd	1,020	1962	1,000	20-12	1,000	399-1,000	2/64 12/65	224.5 234.7	8/65	2,250	330.0	X	X	
12acc	1,070	1954	870	20-16-12	870	80-870	1/61 12/65	258.2 279.7	---	---	----	X	---	
12add	1,085	1954	715	20-16	715	200-715	1/55 12/65	218.8 303.8	9/57	1,120	----	X	---	
12cdc	1,053	1955	941	20-16	941	200-941	9/60 12/65	249.1 264.7	8/65	1,100 E	----	X	---	
12ddd	---	----	188	6	37	----	6/49 2/51	184.6 185.4	---	---	----	---	---	

Table 1.--Records of wells in the Waterman Wash area—Continued

Well location	Land-surface altitude (feet above mean sea level)	Date completed (year)	Reported depth (feet)	Diameter of casing (inches)	Depth of casing (feet)	Perforated interval (feet below land surface)	Water level		Pumping data			Well log	Chemical analysis	Remarks
							Date (month, year)	Feet below land surface	Date (month, year)	Yield (gpm)	Pumping level (feet below land surface)			
(C-2-2)13aaa	1, 078	1953	617	20-12	617	159-617	12/65	300. 8	8/65	1, 250	373. 0	X	---	
13acb	1, 063	1956	800	20-16	770	122-770 OH 770-800	12/65	275. 5	---	---	----	X	---	
13ccb	1, 042	1964	1, 477	20-16-12	1, 477	250-1, 477	2/65 12/65	250. 4 253. 6	8/65	2, 100	----	X	---	
13daa	1, 080	1952	680	20-16	639	200-639 OH 639-680	4/52 12/65	180. 8 294. 0	8/57	658	----	---	---	
14add	1, 015	1958	992	20-16	930	300-930 OH 930-992	1/61	225. 0	8/65	2, 290	324. 8	X	X	
14daa	1, 042	----	---	6	---	----	6/49	143. 5	---	---	----	---	---	
17adc	1, 039	1951	1, 002	20-16	1, 002	498-1, 002	1/66	255. 2	8/65	2, 320	344. 5	X	X	
22dcc	1, 082	1950	1, 250	20-16	1, 236	241-1, 236 OH 1, 236-1, 250	1/61	272. 3	8/65	2, 150	317. 0	X	X	
23aba	1, 037	----	---	---	---	----	2/51 1/59	142. 0 156. 8	---	---	----	---	---	
23ccc	1, 074	----	1, 263	20	1, 200	205-1, 200 OH 1, 200-1, 263	1/61 1/66	252. 7 278. 6	8/65	1, 570	306. 9	X	X	
23dcb	1, 054	----	174	---	---	----	6/49 4/52	159. 6 168. 5	---	---	----	---	---	Destroyed.
24aaa1	---	----	156	6	---	----	---	---	---	---	----	---	---	Do.
24aaa2	1, 077	1951	930	20-16	785	214-785 OH 785-930	2/54 12/65	194. 1 286. 2	8/65	1, 570	----	X	---	
25ccc	1, 078	1955	882	20	868	290-868 OH 868-882	1/56 1/66	223. 1 278. 1	8/65	2, 750	316. 9	---	X	Hydrograph shown on figure 6.
26acc	1, 078	1964	1, 100	20-16	1, 100	314-1, 100	1/66	276. 8	8/65	1, 760	299. 6	X	X	
26ccc	1, 100	1952	1, 031	20-16	1, 000	240-1, 000 OH 1, 000-1, 031	---	---	8/65	2, 880	367. 1	X	X	
27cbb	1, 115	1951	1, 055	20-16	1, 028	250-1, 028 OH 1, 028-1, 055	1/66	316. 2	8/65	2, 330	398. 9	---	X	
27ccc	1, 135	1953	940	20-16	895	295-895 OH 895-940	2/54 1/66	260. 2 333. 7	8/65	1, 550	391. 0	X	X	
27cdd	1, 120	1951	1, 084	20-16	1, 082	243-1, 082 OH 1, 082-1, 084	1/66	324. 0	7/66	1, 560	----	X	X	
35dcc	1, 105	1951	1, 037	20-16	806	202-806 OH 806-1, 037	4/52 1/66	212. 6 304. 5	8/65	2, 310	325. 9	---	---	

Table 1. --Records of wells in the Waterman Wash area—Continued

Well location	Land-surface altitude (feet above mean sea level)	Date completed (year)	Reported depth (feet)	Diameter of casing (inches)	Depth of casing (feet)	Perforated interval (feet below land surface)	Water level		Pumping data			Well log	Chemical analysis	Remarks
							Date (month, year)	Feet below land surface	Date (month, year)	Yield (gpm)	Pumping level (feet below land surface)			
(C-2-2)36dcc	1,100	1957	875	20-16	856	235-856 OH 856-875	1/66	306.1	8/65	2,090	338.8	X	X	
(C-3-1)1bca	1,258	----	371	8	---	----	6/49 1/66	329.7 352.2	---	---	----	---	---	Depth formerly reported as 350 feet (White, 1963). Hydrograph shown on figure 6.
7acc	1,135	1956	----	---	---	----	10/64	320 R	---	---	----	---	---	
9dcb	1,135	----	----	---	---	----	6/49	211.3	---	---	----	---	---	
21dcc	1,182	1958	1,175	20-16	1,020	200-1,020 OH 1,020-1,175	1/59 1/66	293.4 302.0	8/65	2,020	349.8	X	X	Hydrograph shown on figure 6.
28ddd	1,208	1961	1,175	20-16	1,100	300-1,100 OH 1,100-1,175	3/62 1/66	297.8 325.6	8/65	3,690	411.5	X	X	
34dcd	1,243	1962	1,148	20-16	1,148	250-1,148	1/66	357.2	8/65	2,350	434.2	X	---	
34ddb	1,240	----	368	12	---	----	10/53 1/59 3/60	342.6 346.4 Dry at 349	---	---	----	---	---	
36aaa	1,203	----	----	6	---	----	2/54 1/55	291.4 291.7	---	---	----	---	---	
(C-3-2)1cbb	1,120	1935	237	20-8	---	----	---	---	---	---	----	---	---	
(D-4-1)21ada	1,288	----	----	20	---	----	1/55 1/61	367.5 367.9	---	---	----	---	---	
21ccc	1,313	1963	846	16-14	840	----	2/64 1/66	390.7 392.6	---	---	----	X	---	
23aba	1,280	----	176	---	---	----	8/49	Dry	---	---	----	---	---	
26bac	1,312	1948	370	6	---	----	8/49	330 R	8/49	10 E	----	---	---	
28bbc	1,320	1940	504	12	---	----	10/41	440 R	10/41	100 R	----	---	---	
28cdd	1,338	1951	750	20	750	300-750	4/52 1/66	398.5 401.2	---	---	----	X	---	Formerly reported as (D-4-1)28dcc (White, 1963).
29abd	1,328	1918	452	12	---	----	4/52	400.6	---	---	----	---	---	
(D-5-1)1dca	1,375	----	352	20	---	----	3/53 1/58	282.4 299.2	---	---	----	---	---	
(D-5-2)7ccd	1,390	----	----	---	---	----	5/53	274.9	---	---	----	---	---	

Table 2.--Chemical analyses of water from selected wells in the Waterman Wash area

[Analyses by U.S. Geological Survey. Results in milligrams per liter except as indicated. Dissolved solids: Dissolved-solids values represent sum of the determined constituents in solution]

Well location	Date of collection (month, year)	Reported depth (feet)	Temperature (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids		Hardness as $CaCO_3$		Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
													Milligrams per liter	Tons per acre-foot	Calcium, magnesium	Non-carbonate			
(C-2-1)18daa	7/66	958	36	28	88	3.8	570	36	0	210	860	5.4	1,780	2.42	235	206	16	3,170	6.4
19daa	7/66	---	33	24	41	2.4	406	50	0	134	570	4.0	1,210	1.65	112	71	17	2,200	6.4
20baa	7/66	1,549	33	30	96	6.0	608	40	0	180	960	4.7	1,900	2.58	264	231	16	3,450	7.5
20dba	7/66	717	36	26	102	9.1	619	42	0	202	980	4.8	1,960	2.67	292	258	16	3,510	6.8
28dad	7/66	805	37	25	94	7.7	490	58	0	210	750	3.1	1,610	2.19	266	219	13	2,880	6.7
29bab	7/66	809	35	79	40	6.1	476	30	35	156	640	4.5	1,450	1.97	125	42	18	2,530	9.3
29daa	7/66	936	36	105	44	8.3	438	36	47	153	580	4.4	1,400	1.90	144	36	16	2,380	9.5
30bdd	7/66	---	28	23	30	6.6	346	78	0	161	438	2.2	1,040	1.41	102	38	15	1,910	6.7
30dba	7/66	600	34	55	33	5.7	352	108	4	133	448	2.1	1,080	1.47	106	11	15	1,910	8.5
32ada	7/66	880	35	23	34	7.0	330	82	0	146	432	1.8	1,010	1.37	114	47	13	1,850	7.5
33dcc	7/66	1,073	--	23	31	5.5	284	94	0	126	360	.9	876	1.19	100	23	12	1,580	7.1
(C-2-2)8cad	7/66	605	29	28	9.6	1.2	162	300	0	25	65	7.0	446	.61	30	0	13	769	7.3
9bdd	7/66	815	28	114	14	.7	126	214	47	10	22	6.5	445	.61	38	0	9	577	9.2
9cbb	7/66	973	29	77	12	.5	161	214	30	28	77	7.0	498	.68	32	0	12	769	9.1
10dda	9/60	1,000	--	32	28	1.7	213	196	0	65	199	6.6	659	.90	77	0	11	1,140	7.3
	7/66		29	28	24	1.0	224	180	0	74	220	6.0	666	.91	64	0	12	1,160	7.3
11ccd	7/66	1,000	29	138	51	6.6	342	90	63	111	418	5.5	1,180	1.60	154	0	12	1,860	9.3
14add	7/66	992	32	35	63	4.6	395	80	0	157	562	5.6	1,260	1.71	176	111	13	2,310	7.3
17adc	7/66	1,002	31	25	32	4.4	333	78	0	156	412	5.6	1,010	1.37	98	34	15	1,820	6.9
22dcc	7/66	1,250	31	29	13	4.2	233	124	0	101	240	4.1	685	.93	50	0	14	1,250	8.2
23ccc	4/52	1,263	31	20	17	3.4	264	101	0	116	282	2.6	783	1.06	56	0	15	1,370	---
	7/66		--	98	25	4.2	256	76	39	108	275	3.5	846	1.15	80	0	12	1,380	9.2
25ccc	7/66	882	--	23	28	5.8	257	114	0	144	282	4.5	800	1.09	94	0	12	1,460	6.9
26acc	7/66	1,100	32	92	23	6.0	298	74	39	138	322	3.1	957	1.30	82	0	14	1,580	9.3
26ccc	7/66	1,031	32	30	23	6.9	358	164	0	190	372	2.8	1,060	1.44	86	0	17	1,870	7.6
27cbb	7/66	1,055	32	44	47	5.6	282	116	0	118	370	5.2	929	1.26	140	45	10	1,670	7.2
27ccc	7/66	940	36	30	21	1.3	294	84	0	106	358	5.3	857	1.17	58	0	17	1,540	7.1
27cdd	7/66	1,084	36	26	102	9.1	325	96	0	284	435	4.6	1,230	1.67	292	214	8	2,180	6.9
36dcc	7/66	875	32	22	7.2	2.4	214	144	0	90	192	4.1	603	.82	28	0	18	1,100	7.1
(C-3-1)21dcc	7/66	1,175	--	110	19	6.0	164	112	43	74	132	1.2	604	.82	72	0	8	981	9.3
28ddd	7/66	1,175	28	30	23	5.5	147	160	0	81	128	1.1	495	.67	80	0	7	880	7.5

Table 3. --Field determinations of temperature and specific conductance and calculated dissolved-solids concentrations in water from selected wells in the Waterman Wash area

Well location	Date of collection (month, year)	Reported depth (feet)	Temperature (°C)	Dissolved solids		Specific conductance (micromhos at 25°C)
				Milligrams per liter	Tons per acre-foot	
(C-2-1)19aad	7/66	802	34	1,480	2.01	2,650
19baa	7/66	1,139	33	1,090	1.48	1,950
29caa	9/60	809	--	1,130	1.54	2,050
	7/66		35	1,120	1.52	2,000
33aaa	7/66	1,030	37	1,340	1.82	2,400
(C-2-2)8dad	9/60	465	--	462	.63	766
	7/66		28	756	1.03	1,350
9cdd	7/66	515	29	543	.74	970
10ccc	7/66	750	29	571	.78	1,020
13aaa	7/66	617	32	991	1.35	1,770
13ccb	7/66	1,477	31	504	.69	900
35dcc	7/66	1,037	32	644	.88	1,150
(C-3-1)34dcd	7/66	1,148	29	476	.65	850

ARIZONA STATE LAND DEPARTMENT WATER-RESOURCES REPORTS
(Continued from inside front cover)

No.

17. Effects of ground-water withdrawal, 1954-63, in the lower Harquahala Plains, Maricopa County, Arizona, by R. S. Stulik: 8 p., 5 figs., 1964.

18. Basic ground-water data for western Pinal County, Arizona, by W. F. Hardt, R. E. Cattany, and L. R. Kister: 59 p., 4 figs., 1964.

19. Annual report on ground water in Arizona, spring 1963 to spring 1964, by N. D. White, R. S. Stulik, E. K. Morse, and others: 60 p., 27 figs., 1964.

20. Hydrologic and drill-hole data, San Xavier Indian Reservation and vicinity, Pima County, Arizona, by L. A. Heindl and N. D. White: 48 p., 3 figs., 1965.

21. Basic hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, and Hidalgo County, New Mexico, by N. D. White and C. R. Smith: 42 p., 4 figs., 1965.

22. Bibliography of U.S. Geological Survey water-resources reports, Arizona, 1891 to 1965, compiled by the Arizona District, Water Resources Division, U. S. Geological Survey: 59 p., 1965.

23. Geohydrology of the Dateland-Hyder area, Maricopa and Yuma Counties, Arizona, by W. G. Weist, Jr.: 46 p., 8 figs., 1965.

24. Annual report on ground water in Arizona, spring 1964 to spring 1965, by N. D. White and others: 62 p., 22 figs., 1965.

25. An appraisal of the ground-water resources of Avra and Altar Valleys, Pima County, Arizona, by N. D. White, W. G. Matlock, and H. C. Schwalen: 66 p., 12 figs., 1966.

26. Basic hydrologic data of the Hualapai, Sacramento, and Big Sandy Valleys, Mohave County, Arizona, by J. B. Gillespie, C. B. Bentley, and William Kam: 39 p., 6 figs., 1966.

No.

27. Basic ground-water data for western Salt River Valley, Maricopa County, Arizona, by William Kam, H. H. Schumann, L. R. Kister, and F. E. Arteaga: 72 p., 11 figs., 1966.

28. Anticipated changes in the flow regimen caused by the addition of water to the East Verde River, Arizona, by H. W. Hjalmarson and E. S. Davidson: 10 p., 3 figs., 1966.

29. Infiltration and recharge from the flow of April 1965 in the Salt River near Phoenix, Arizona, by P. C. Briggs and L. L. Werho: 12 p., 7 figs., 1966.

30. Hydrologic conditions in the Douglas basin, Cochise County, Arizona, by N. D. White and Dallas Childers: 26 p., 9 figs., 1967.

31. Compilation of flood data for Maricopa County, Arizona, through September 1965, by L. L. Werho: 36 p., 1 fig., 1967.

*32. Annual report on ground water in Arizona, spring 1965 to spring 1966, by E. B. Hodges and others: 61 p., 22 figs., 1967.

33. Basic ground-water data for southern Coconino County, Arizona, by E. H. McGavock: 49 p., 4 figs., 1968.

34. Spring flow into the Colorado River—Lees Ferry to Lake Mead, Arizona, by P. W. Johnson and R. B. Sanderson: 26 p., 5 figs., 1968.

35. Ground water in Paradise Valley, Maricopa County, Arizona, by F. E. Arteaga, N. D. White, M. E. Cooley, and A. F. Sutheimer: 76 p., 15 figs., 1968.

36. Annual report on ground water in Arizona, spring 1966 to spring 1967, by C. J. Cox and others: 43 p., 30 figs., 1968.

37. Ground-water conditions in the Waterman Wash area, Maricopa and Pinal Counties, Arizona, by E. E. Denis: 23 p., 9 figs., 1968.